Claims

What is claimed is:

1. An apparatus for separating ions comprising:

an electrode stack having a length and comprising a plurality of electrodes, each electrode of the electrode stack being spaced apart from an adjacent electrode of the electrode stack in a direction along the length of the electrode stack, each electrode of the electrode stack having an edge defining a portion of an edge of the electrode stack;

at least an electrode spaced apart from the edge of the electrode stack in a direction transverse to the length of the electrode stack, the space between the at least an electrode and the edge of the electrode stack defining an analytical gap for allowing ions to propagate therebetween; and,

at least an electrical controller for electrically coupling to at least one of an electrode of the plurality of electrodes of the electrode stack and the at least an electrode, for applying an asymmetric waveform voltage between the electrode of the plurality of electrodes of the electrode stack and the at least an electrode and for applying a direct current voltage between the electrode of the plurality of electrodes of the electrode stack and the at least an electrode so as to establish an electric field within the analytical gap.

2. An apparatus according to claim 1, wherein the edge of each electrode of the electrode stack is approximately aligned with an edge of every other electrode of the electrode stack so as to define the edge of the electrode stack.

3. An apparatus according to any one of claims 1 and 2, wherein a spacing between any two adjacent electrodes of the electrode stack is approximately a same spacing.

4. An apparatus according to any one of claims 1, 2, and 3, wherein each electrode of the electrode stack comprises an electrode plate.

5. An apparatus according to any one of claims 1, 2, and 3, wherein each electrode of the electrode stack comprises an electrode rod.

6. An apparatus according to any one of claims 1, 2, 3, and 4, wherein the electrode stack is relatively moveable in a direction toward the at least an electrode, such that a width of the analytical gap is controllably variable.

7. An apparatus according to any one of claims 1, 2, 3, 4, and 6, wherein the at least an electrode comprises an electrode plate having a length and being oriented so as to maintain an approximately uniform spacing along the length of the electrode plate to the edge of the electrode stack.

8. An apparatus according to claim 7, wherein the electrode plate is curved in a direction along the length of the electrode plate.

9. An apparatus according to claim 7, wherein the electrode plate is curved in a direction transverse to length of the electrode plate.

10. An apparatus according to any one of claims 1, 2, 3, 4, and 6, wherein the at least an electrode comprises a second electrode stack having a length, the length of the second electrode stack being substantially similar to the length of the first electrode stack.

11. An apparatus according to claim 10, wherein the second electrode stack comprises a plurality of electrodes, each electrode of the second electrode stack being spaced apart from an adjacent electrode of the second electrode stack in a direction along the length of the second electrode stack, each electrode of the second electrode stack having an edge defining a portion of an edge of the second electrode stack.

12. An apparatus according to claim 11, wherein the edge of each electrode of the second electrode stack is aligned with an edge of every other electrode of the second electrode stack so as to define the edge of the second electrode stack.

13. An apparatus according to any one of claims 11, and 12, wherein the second electrode stack is disposed such that the edge of the second electrode stack faces the edge of the electrode stack in a spaced apart arrangement, the space between the edge of the second electrode stack and the edge of the electrode stack defining the analytical gap.

14. An apparatus according to any one of claims 10, 11, 12, and 13, wherein the second electrode stack is moveable relative to the first electrode stack in a direction along the length of the second electrode stack.

15. An apparatus according to any one of claims 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, and 14, comprising an ion outlet plate disposed adjacent to a first end of the electrode stack and defining an ion outlet for extracting ions from the analytical gap.

16. An apparatus according to claim 15, comprising an ion inlet plate disposed adjacent to a second end of the electrode stack opposite the first end and defining an ion inlet for introducing ions into the analytical gap.

17. An apparatus according to claim 15, comprising means for introducing ions into the analytical gap via a space between at least an electrode of the electrode stack and an adjacent electrode of the electrode stack.

18. An apparatus according to claim 17, wherein the means for introducing ions into the analytical gap comprises an ion inlet.

19. An apparatus according to any one of claims 15 and 17, comprising a gas inlet for introducing a flow of a gas into the analytical gap for carrying the ions in a direction towards the ion outlet.

20. An apparatus according to claim 19, wherein the gas inlet is disposed at a point that is more distal from the ion outlet relative to the ion inlet.

21. An apparatus for separating ions comprising:

a first electrode stack having a length and comprising a plurality of electrode plates, each electrode plate of the first electrode stack being spaced apart from an adjacent electrode plate in a direction along the length of the first electrode stack, each electrode plate of the first electrode stack having an edge defining a portion of an edge of the first electrode stack;

a second electrode stack having a length, the length of the second electrode stack being substantially similar to the length of the first electrode stack, the second electrode stack comprising a second plurality of electrode plates, each electrode plate of the second electrode stack being spaced apart from an adjacent electrode plate in a direction along the length of the second electrode stack, each electrode plate of the second electrode stack having an edge defining an edge of the second electrode stack, the edge of the second electrode stack facing the edge of the first electrode stack in a spaced apart arrangement and defining an analytical gap for allowing ions to propagate therebetween; and,

at least an electrical controller for electrically coupling to at least one of an electrode plate of the first plurality of electrode plates of the first electrode stack and an electrode plate of the second plurality of electrode plates of the second electrode stack, for applying an asymmetric waveform voltage between the first electrode stack and the second electrode stack and for applying a direct current voltage between the first electrode stack and the second electrode stack so as to establish an electric field within the analytical gap.

22. An apparatus according to claim 21, comprising an ion outlet plate disposed adjacent to a first end of the analytical gap and defining an ion outlet for extracting ions from the analytical gap proximate the first end.

23. An apparatus according to claim 22, comprising an ion inlet plate disposed adjacent to a second end of the analytical gap opposite the first end and defining an ion inlet for introducing ions into the analytical gap at the second end.

24. An apparatus according to claim 22, comprising means for introducing ions into the analytical gap via at least a space between at least an electrode of one of the first electrode stack and the second electrode stack and an adjacent electrode of the one of the first electrode stack and the second electrode stack.

25. An apparatus according to claim 24, wherein the means for introducing ions into the analytical gap comprises an ion inlet.

26. An apparatus according to any one of claims 21 to 25, wherein the edge of each electrode plate of the first electrode stack is aligned with an edge of every other electrode plate of the first electrode stack, and wherein the edge of each electrode plate of the second electrode stack is aligned with an edge of every other electrode plate of the second electrode stack.

27. An apparatus according to any one of claims 21 to 26, comprising a gas inlet for introducing a flow of a gas into the analytical gap.

28. An apparatus for separating ions comprising:

an electrode stack having a length and comprising a plurality of electrodes, each electrode of the electrode stack being spaced apart from an adjacent electrode in a direction along the length of the electrode stack;

an electrode plate spaced apart from the electrode stack and having a surface facing the plurality of electrodes of the electrode stack and being oriented such that a minimum distance between each electrode of the electrode stack and the surface of the electrode plate is substantially a same minimum distance, as measured in a direction normal to a portion of the surface of the electrode plate proximate each electrode of the electrode stack, the space between the flat electrode plate and the electrode stack defining an analytical gap for allowing ions to propagate therethrough in a direction along the length of the electrode stack; and,

at least an electrical controller for electrically coupling to at least one of an electrode of the plurality of electrodes of the electrode stack and the flat electrode plate,

for applying an asymmetric waveform voltage between the electrode of the plurality of electrodes of the electrode stack and the flat electrode plate and for applying a direct current voltage between the electrode of the plurality of electrodes of the electrode stack and the flat electrode plate so as to establish an electric field within the analytical gap.

29. An apparatus according to claim 28, wherein each electrode of the electrode stack is disposed approximately parallel to the adjacent electrode.

30. An apparatus according to any one of claims 28 and 29, wherein each electrode of the electrode stack has an edge that is aligned with an edge of every other electrode of the electrode stack so as to define an edge of the electrode stack.

31. An apparatus according to any one of claims 28, 29, and 30, wherein the electrode plate is a flat electrode plate.

32. An apparatus according to any one of claims 28, 29, 30, and 31, comprising an ion outlet plate disposed adjacent to a first end of the analytical gap and defining an ion outlet for extracting ions from the analytical gap proximate the first end.

33. An apparatus according to claim 32, comprising an ion inlet plate disposed adjacent to a second end of the analytical gap opposite the first end and defining an ion inlet for introducing ions into the analytical gap at the second end.

34. An apparatus according to claim 32, comprising means for introducing ions into the analytical gap via a space between at least an electrode of the electrode stack and an adjacent electrode of the electrode stack.

35. An apparatus according to claim 34, wherein the means for introducing ions into the analytical gap comprises an ion inlet.

36. An apparatus according to any one of claims 32 to 35, comprising a gas inlet for introducing a flow of a gas into the analytical gap for carrying the ions in a direction towards the ion outlet.

37. An apparatus according to claim 28, wherein the electrode plate is curved in a direction along the length of the electrode stack.

38. An apparatus according to claim 28, wherein the electrode plate is curved in a direction transverse to the length of the electrode stack.

39. An apparatus for separating ions comprising:

an electrode assembly including;

at least a first electrode comprising a first plurality of electrode portions;

at least a second electrode comprising a second plurality of electrode portions arranged in alternating sequence with the first plurality of electrode portions along a first direction;

an electrode plate spaced apart from the first plurality of electrode portions and the second plurality of electrode portions in a second direction transverse to the first direction, the space between the electrode plate and the first plurality of electrode portions and the second plurality of electrode portions defining an analytical gap for allowing ions to propagate therethrough along approximately the first direction; and,

at least an electrical controller for electrically coupling to at least one of the at least a first electrode, the at least a second electrode and the electrode plate for establishing an electrical field within the analytical gap resulting from the application of an asymmetric waveform voltage and a direct current voltage between the at least a first electrode, the at least a second electrode and the electrode plate,

whereby ions having suitable high field mobility properties for a given combination of applied asymmetric waveform voltage and direct current voltage are selectively transmitted through the analytical gap.

40. An apparatus according to claim 39, wherein at least one of the first plurality of electrode portions and the second plurality of electrode portions is a portion of a formed electrode.

41. An apparatus according to any one of claims 39 and 40, wherein the electrode plate is a flat electrode plate.

42. An apparatus according to claim 40, wherein the other one of the at least one of the first plurality of electrode portions and the second plurality of electrode portions comprises an electrode stack having a length and comprising a plurality of rods, each rod of the plurality of rods being spaced apart from an adjacent rod in a direction along the length of the electrode stack.

43. An apparatus for separating ions comprising:

at least an electrical controller; and,

an electrode assembly including;

at least a first electrode comprising a first plurality of electrode portions in electrical communication with the at least an electrical controller for receiving at least an asymmetric waveform voltage;

at least a second electrode comprising a second plurality of electrode portions arranged in alternating sequence with the first plurality of electrode portions along a first direction, the second plurality of electrode portions in electrical communication with the at least an electrical controller for receiving a direct current voltage;

at least a third electrode spaced apart from the at least a first electrode and the at least a second electrode in a second direction transverse to the first direction, the at least a third electrode comprising a third plurality of electrode portions in electrical communication with the at least an electrical controller for receiving at least an asymmetric waveform voltage; and,

at least a fourth electrode comprising a fourth plurality of electrode portions arranged in alternating sequence with the third plurality of electrode portions along the first direction, the fourth plurality of electrode portions in electrical communication with the at least an electrical controller for receiving a direct current voltage,

wherein the space between the at least a third electrode and the at least a first electrode defines an analytical gap for selectively transmitting ions passing therethrough along approximately the first direction at a given combination of applied asymmetric waveform and direct current voltages.

44. A method of separating ions comprising the steps of:

introducing ions into a first space defined between adjacent electrode plates of a stacked parallel plate high field asymmetric waveform ion mobility spectrometer;

performing a first separation of the ions within the first space, to selectively transmit a subset of the ions along a first direction between a first end of the electrode plates and a second end of the electrode plates that is opposite the first end;

performing a second separation of the ions within a second space defined between the second end of the electrode plates and at least another electrode, to selectively transmit some of the subset of the ions along a second direction approximately transverse to the first direction between the second end of the electrode plates and an ion outlet.

45. A method according to claim 44, comprising the step of providing a first flow of a gas within the first space along the first direction between the first end of the electrode plates and a second end of the electrode plates and providing a second flow of a gas within the second space along the second direction and toward the ion outlet.

46. A method according to claim 44, comprising the step of providing a flow of a gas within the first space along the first direction between the first end of the electrode plates and a second end of the electrode plates and providing a potential gradient within the second space for directing ions propagating therein along the second direction toward the ion outlet.

47. A method of separating ions comprising the steps of:

providing a high field asymmetric waveform ion mobility spectrometer including a plurality of spaced-apart electrodes that are stacked one relative to another in a first direction, and at least another electrode that is spaced apart from the plurality of spaced-apart electrodes in a second direction transverse to the first direction, the space between the plurality of spaced-apart electrodes and the at least another electrode defining an analytical gap;

providing an electric field within the analytical gap by the application of an asymmetric waveform voltage between the plurality of spaced-apart electrodes and the at least another electrode and by the application of a direct current voltage between the plurality of spaced-apart electrodes and the at least another electrode; and,

selectively transmitting ions within the analytical gap along the first direction between an ion inlet end and an ion outlet end of the analytical gap.

48. A method according to claim 47, comprising the step of providing a flow of a gas along the first direction within the analytical gap for transporting ions in a direction toward the ion outlet end of the analytical gap.